COST EFFECTIVE METHODOLOGY FOR HARNESSING RENEWABLE ENERGY IN REMOTE AREAS

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Abstract

Sustainable but also environmentally friendly. Renewable energy sources such as solar, wind, hydro, and biomass have emerged as viable options to meet the growing energy demands of rural areas. These sources not only provide clean and green energy but also have the potential to create employment opportunities and boost local economies.

Investing in renewable energy infrastructure in rural areas can help bridge the energy gap and improve the quality of life for millions of people. It can also reduce dependency on imported fossil fuels, enhance energy security, and mitigate the effects of climate change.

Furthermore, promoting renewable energy in rural areas can empower communities to become self-sufficient and resilient in the face of natural disasters or other disruptions to traditional energy sources. By harnessing the power of nature, we can create a more sustainable future for all while ensuring equitable access to reliable and affordable energy for everyone.

The optimization model takes into account the variability of renewable energy sources such as solar, wind, and biomass, as well as the energy demand of the village. By considering factors such as energy storage capacity, system reliability, and environmental impact, the model can determine the most cost-effective and efficient combination of renewable energy technologies to meet the village's energy needs.

Additionally, the goal programming method allows for trade-offs between cost and efficiency to be made in order to find the best overall solution. This approach ensures that the Integrated Renewable Energy System is not only economically viable but also sustainable in the long term.

Overall, this optimization model provides a valuable tool for decision-makers looking to implement renewable energy systems in remote areas. By maximizing the use of available resources and minimizing costs, it can help bring clean and reliable energy to communities that may otherwise be underserved.

The aforesaid method is applied to a village selected for study. Cooking, lighting and mechanical energy requirements of the village are estimated along with the available renewable resources and the method is applied to size the renewable energy conversion system (RECS).

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Introduction

The potential of renewable energy sources such as micro hydro energy, biomass energy, wind energy and solar energy have been assessed for the study area. The efficiency of conversion of various resources to various needs is estimated. The sizing of various renewable energy conversion systems has been done based on resource potential available and efficiency of utilization of resources. The cost analysis of MHP, biomass, wind and SPV system has been carried out here. Lastly the various readily available renewable energy conversion systems are looked for and comparison of size of the required system is done with that of readily available system ratings.

Methodology Adopted

The steps adopted for addressing the objective are as follows:

- Selection of Village: As such definition of remote villages have not specified in the literature studied and no criterion has been categorically stated by Government of India for the identification of 18000 remote villages, which are to be electrified by renewable resources. For the purpose of study, the village that is far from road communication and not connected with grid is considered remote. Accordingly, a village is selected where there is enough scope of renewable resources and has characteristics to truly represent the area in terms of accessibility, socially, economically and geographically.
- Assessment of the Resources: The assessment of resources has to be seen in the context of benefit expected to accrue. The availability of long term data on solar, wind and hydro requires a good amount of time and financial resources. The benefit expected to accrue may not outweighs the cost spent on collection of data. At the same time it should be ensured that the compromise on accuracy and consistency of data in the pretext of cost involved in collection should not lead to the development of system which is over size or under size. As the collection of data for wind and solar is costly and time consuming the data of nearest wind monitoring station can be taken for wind energy potential assessment. Similarly for solar the long term data of the nearest area is available in literature. The assessment of biomass potential is made from the survey of cattle population carried category wise and sample survey of types of crop cultivated and their production. The quantity of dung excretion and its production potential of biogas is assessed by population of cattle. Similarly, the agricultural residues can be assessed by co-relating the agriculture land with the crop cultivated and their productivity. Hydro power potential is assessed measuring head and discharge.
- Assessment of energy consumption pattern and quality of energy required: The assessment of electrical load is carried out first by assessing average number of rooms available per household that has been determined by doing a sample survey of different sizes of households. The requirement of electricity is related to number of rooms and the commonly used appliances. The requirement of energy for cooking assessed by research scholars is available in the literature.
- Identification of Renewable Energy technologies: The renewable resources available in the area guide the selection of renewable energy technologies. Based upon the collected data, the unit cost of energy of each resources calculated. The efficiency for various resource need combination is also determined.
- Formulation of IRES model: Integrated Renewable Energy System (IRES) model is formulated based on objective

selected for optimization. The approach employs a linear programming technique for the design of integrated renewable energy systems. The technique is based on minimizing an objective function subject to a set of energy and power constraints related to resource availabilities and load requirements.

- Optimization: Based on the objective function and constraints, the IRES models is optimized using TORA SOFTWARE for solving linear equations. The optimization will yield optimum allocation of quantum of resources required to fulfill the energy needs in a way to utilize the available resources in most cost effective and efficient manner.
- Assessment of availability of the standard equipments suitable for the rural area needs is made and compared with the availability of the sizes of equipments selected for the area.

Efficiencies of Various Energy Conversion Systems

Each of the renewable energies can be converted to meet the variety of end needs and each of such combinations of conversion will have different efficiency. For example hydro energy can be converted to mechanical, electrical and heat energy through a series of conversions. The hydro energy can be converted to rotating shaft power by turbine which can be utilized or can be further converted to electrical energy by coupling generator for lighting use. The use of electrical energy can be done for cooking by hot plate at consumer end. At every down stage of energy conversion there will be loss of efficiency. The utilization of energy at each of the stage can be done as per the requirement of that kind of energy as it would be imprudent to first generate electricity then convert it to rotating shaft power by using electric motor and waste energy when the rotating shaft power is directly available from turbine output. This will enable us to achieve maximum possible efficient utilization of resources by avoiding some of the energy conversions.

Similarly Biogas can be used for cooking directly in gas burner or it can be used for generating rotating shaft power and electricity by Duel fuel engine. The solar PV cells are suitable for generating electricity which can be further quite conveniently used for water lifting. However the use of solar energy for cooking purpose using hot plate will be quite costly. Wind as hydro power is most suitable for rotating shaft power and electricity. In order to assess the suitability of each of the energy sources for each of the needs it will be imperative to find the energy conversion efficiency of each of the stage. In order to arrive at the efficiency at any stage the efficiency of all succeeding conversion efficiency is multiplied and is done as follows:

For Hydro

η_{hy-m} - (Efficiency of hydro to mechanical energy conversion)

$\eta_{hy-e} = \eta_{hy-m} \times \eta_{m-e}$ (Total efficiency of conversion to electrical energy)

$\eta_{hy-h} = \eta_{hy-m} \times \eta_{m-e} \times \eta_{e-h}$ (Total efficiency of conversion to heat energy)

For Biogass (BGS)

η_{b-h} - (Efficiency of Biomass to heat energy conversion)

$\eta_{b-m} = \eta_{b-h} \times \eta_{h-m}$ (Total efficiency of conversion to mechanical energy Using Dual Fuel Mode Diesel Generating Set)

$\eta_{b-e} = \eta_{b-h} \times \eta_{h-m} \times \eta_{m-e}$ (Total efficiency of conversion to electrical energy)

For Biomass(BES)

η_{bes-m} Efficiency of Biomass (BES) to mechanical output Using Engine

$\eta_{bes-e} = \eta_{bes-m} \times \eta_{e-m}$ Efficiency of Biomass (BES) to electricity :

For Wind

η_{w-m} - (Efficiency of wind to mechanical energy conversion)

$\eta_{w-e} = \eta_{w-m} \times \eta_{m-e}$ (Total efficiency of conversion to electrical energy)

$\eta_{w-h} = \eta_{w-m} \times \eta_{m-e} \times \eta_{e-h}$ (Total efficiency of conversion to heat energy)

For Solar

η_{pv-e} - (Efficiency of PV cells to electrical energy conversion)

$\eta_{pv-m} = \eta_{pv-e} \times \eta_{e-m}$ (Total efficiency of conversion to mechanical energy)

$\eta_{pv-h} = \eta_{pv-e} \times \eta_{e-h}$ (Total efficiency of conversion to heat energy)

Using above mentioned approach the efficiency at every stage of conversions for all the available resources is determined. The efficiency of hydro to mechanical is assumed to be 70% considering some of the energy would be lost in civil structures works like channel, penstock, etc. and turbines. The best turbines can have hydraulic efficiencies in the range 80 to over 90% (higher than most other prime movers), although this will reduce with size. Micro hydro systems tend to be in the range 60 to 80% efficient [1]. The efficiency of generator to convert mechanical shaft output power to electricity is assumed 95% for all the resources. Similarly the conversion of electricity to heat is 70% which is the conversion efficiency associated with the electric hot plate [2]. The conversion of solar PV energy from electricity to cooking is quite illogical when the other rational method of using solar concentrator (Cooker) is available, so its value is taken zero for computational purpose. Similarly, BES is suitable for electricity generation and/or obtaining rotating shaft power. Its use as heat for cooking is taken as 40% as it can be used by directly in improved stoves.

The efficiencies of conversion of biogas to heat for cooking and solar PV to electricity are available in the literature while the efficiency of wind energy conversion is assumed.

For Hydro

Efficiency of hydro to mechanical energy conversion[(a)] : $\eta_{hy-m} = 65\%^{a}$

Efficiency of mechanical energy to electricity[(a)] : $\eta_{m-e} = 95\%^{b}$ Efficiency of electricity to heat for cooking[2] : $\eta_{e-h} = 70\%$

For Biogas(BGS)

Efficiency of Biogas energy to heat (for cooking) [3] : $\eta_{bgs-h} = 45\%$

Efficiency of Biogas to mechanical output using generator[(a)]: $\eta_{h-m} = 38\%$

Efficiency of Biogas to electricity [4] : $\eta_{bgs-e} = 35.2\%$

For Biomass(BES)

Efficiency of Biomass (BES) to mechanical output Using Engine[(a)] : $\eta_{bes-m} = 38\%$

Efficiency of Biomass (BES) to electricity [4] : $\eta_{bes-e} = 35.2\%$

For Wind

Efficiency of Wind to mechanical energy conversion[(a)] : $\eta_{w-m} = 35\%$

Efficiency of mechanical to electrical[(a)] : $\eta_{m-e} = 95\%$

Efficiency of electrical to heat for cooking[3] : $\eta_{e-h} = 70\%$

For Solar

Efficiency of Solar to electrical energy conversion [5] : $\eta_{pv-e} = 12\%$

Efficiency of Solar to Mechanical energy[(a)] : $\eta_{pv-m} = 10\%$

(a) Assumed

While the conversion efficiency of various resources to meet various demands as determined above has been presented in table 1.

Table 1: The Efficiencies of various conversion systems

Needs / Resources	Mechanical	Electrical	Heat
Hydro (MHP)	0.65	0.60	0.42
Biomass (BGS)	0.38	0.35	0.45
Biomass (BES)	0.38	0.35	0.40
Wind	0.35	0.33	0.23
Solar (PV)	0.10	0.12	

SIZING OF SHP

The general formula for any hydro system's power output is given in equation 1 [6].

$$P = \eta \times \rho \times g \times Q \times H \quad (1)$$

where P is the mechanical power produced at the turbine shaft (Watts), 'η" is the hydraulic efficiency of the power plant including the losses in civil structures, turbines and generator, ρ is the density of water (kg/m^3), g is the acceleration due to gravity (m/s^2), Q is the volume flow rate passing through the turbine (m^3/s), and H is the gross head (m).

The head available at a site can be measured using altimeter or other survey techniques. It is the value of discharge that has crucial impact on the optimal sizing of hydro power plant due to the fact that its availability changes with time. Besides the output power has to be matched with the availability of load, which is again ever changing. The determination of optimal capacity of small hydro plant of run off river is very useful in obtaining optimal energy value. To determine optimal installation capacity of SHPs all technical, economic and reliability indices are to be considered in a trade off relations. It is observed that with the increase in the number of generation units or capacity more investment will be needed and shall be reflected in higher tariff cost if it could not be utilized fully. This will, however, improve the reliability index but reduces plant load factor [7].

The remote areas which are not connected with grid require reliable power. Hence, the generation capacity can be fixed at lowest available discharge which would be available 100% throughout the year. Base on that the total capacity of MHP estimated to be 21kW.

The standard sizes Pelton micro hydro turbines available are presented in table 2

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Table 2: The Standard Pelton Micro Hydro Turbines Available in India[8]

	Runner Dia. (mm)	Runner Dia. (mm)	Runner Dia. (mm)	Runner Dia. (mm)	Runner Dia. (mm)
	225	275	350	425	450
Head (m)	**Turbine Output (kW)**				
40	17	26	41	61	68
50	23	35	57	86	96
60	31	48	75		
70	40	62	94		
80	47	73			
90	56	87			

It is evident that a wide range of standard turbines are available in India but these standard turbines are available for various combinations of head and runner diamater. It can be seen that turbines available for 70 to 90 meter heads have capacities ranging from 47 to 80 kW and none of the standard turbine is suitable. the choice of turbine suitable for particular head and discharge is limited.

The turbine required for the site is of 21 kW capacity suitable for 85 meter head and 0.04 m^3/sec discharge. However the turbine for the site can be manufactured to suit the site and a twenty (20) kW turbine is considered for the village. The energy 122640 kW can be generated with it at 0.7 plant load factor.

Size of Biomass Plant

Biomass Gasifiers

The biomass from forest to the tune of 149325 kg/day , will provide energy 149324 kWh/day[5]. To utilize biomass for electricity generation for six hours a day due to technological & operational limitation and load profile in use of engine continuously the Producer gas generator of size 45 kW electrical output is estimated and used for assessment of cost of energy.

The commonly used small capacity diesel engines in India are of ratings 3 kW, 5kW, 7.5 kW, 12.5kW, 16 kW, 24 kW and 48 kW. The producer gas can be used as a duel fuel mode in any of the Diesel generator by incorporating appropriate size of gasifier. The capacities of readily available gasifiers are shown in table 4. Some of the manufacturers have standardized their 100% producer gas engine as shown in table 3. The standard ratings of gasifiers available are shown in table 4.

It can be seen that 45 kW producer gas generator is not readily available. Either lower capacity 32 kW set or of higher capacity 80 kW set can be selected. But opting for lower capacity set will entail unsatisfied customers while the higher size will lead to loss of power. Both the choices are uneconomical. It would be more appropriate to have a 10 kW and one 32 kW hundred percent producer gas engine. This will have the flexibility in operation and meeting peak load and/or adverse load profile. The output will however can remain same by way of adjusting the time of use minimally as compared to the adjustment of time required had 80 kW generator is selected

Table 3 :Capacities of 100% Producer Gas Generator Available in India

Rated Woody Mass Consumption (kg/hr)	Electrical Output (kW)
15	10
50	32
120	80
180	120
240	160
340	240
480	320
600	400

Table 4 :Capacities of Gasifiers For Thermal Application Available in India

Rated Woody Mass Consumption (kg/hr)	Thermal Application (kWe)
20	20
50	50
75	75
120	120
180	180
270	270
360	360
480	480
600	600

Biogas Digestor

The sizing of biogas plant is based on the output of dung yield as determined , A biogas digester for capacity of utilizing cattle dung 1 kg/day is designed . The density of mix is assumed 1090kg/m3 after mixing of water in the ratio of 1:1. The retention period is taken 55 days on higher side due to higher altitude of the region of study. The Gas yield per kg of wet dung is taken 0.036 m^3 /kg [9] and Calorific value of biogas is 4700 kcal/m^3 [10]

Table 5 : Sizing of Biogas Digester for unit capacity

1	mass of wet dung	kg/day	m	1
2	1 kg of wet dung yield 0.036m3 of gas so m kg would yield	M3	m x 0.036	0.036
3	Energy Output	kWh/day	(mx0.036x 4700)/860=	0.1967
4	Add water in equal quantity		2xm	2
5	Density of mix	Kg/m3	ρ	1090[a]

6	Volume of mix	M3	2xm/ρ	0.002
7	Volume of digestor	M3	2xmxRd/ρ	0.10[a]
8	Additional volume for storage 60% of vol of digester	M3	0.6 x2xmxRd/ρ	0.06
9	Total Volume of Digester in m3	M3	(7)+(8)	0.16
10	So 1 m3 of digestor can produce	kWh/day	(3)/(9)	1.22
11	Or 1 kWh energy require volume of digester equal to CF_{kWh-m3}	M3/day	(9)/(3)	0.821

[a] Assumed, ρ=1090kg/m3 and Retention days,Rd=55 days

It can be seen that one m^3 of biogas digester can yield 1.22 kWh/day of energy and one kg of cattle dung give up 0.1967 kWh of energy. Based on the above calculation to utilize the full available potential of cattle dung of 5375 kg/day the total aggregate capacity of Biogas digester required for the village under study is 860 m^3. It will produce biogas 193 m^3/day which can yield energy 1057 kWh/day (385994 kWh/year).

The standard sizes of biogas digesters have been designed in wide range of capacities starting from 1,2 and 3 m^3 family size digester to 85 m^3 of community size plant. As the cattle dung is available in large quantity it will require very large number of biogas digester if family size digesters are selected. This will require large space and will be expensive. It is therefore proposed to have a numbers of large community size biogas digesters of total capacity of 860 m^3 for the village.

The standard sizes of biogas plants commonly used to utilize above potential are shown in Table 6. As it is evident that biogas digester are designed for large number of unit sizes starting from 1m3 to 85 m3 the required size of 860m3 can be achieved in multiple units of small sizes without any difficulty. It is proposed to have 10 numbers of 85 m^3 biogas digester and six 3 m^3 digester to the houses that lies in extremes of the village.

Table 6: Standard Sizes of Biogas Plants [5]

Category	**Size of Digester / Plants** (m^3)
Family size	1-10
Medium	10-30
Community size	30-85

SIZING OF SOLAR PV SYSTEM

As discussed earlier, a stand alone SPV system consists of a PV array, storage battery and electronic interface. The sizing of SPV system is to find the number and capacity of solar modules including batteries needed to reliably meet the load of a given area throughout the year as per the availability of solar insolation. The total capacity of the system can be determined by applying the concept of peak sun discussed and the size can be determined by knowing how much resources are required to be satisfied in a cost effective and efficient way [11]. The equation 2 can be used for size determination.

$$SPV_R = P_{cap} \times \frac{H_{daily-av}}{H_{peak-sun}} (kWh/day)$$

$$E_{pv} = \eta_{PV} \times SPV_R \quad 2$$

SPV

SPV_R Solar power resources

Under the present study to evaluate the unit cost of energy for the resources 5.012 kWh/m^2/day as the capacity of panel is taken 1 kW assuming 12 % efficiency considered to evaluate the unit cost of energy[5].

The standard sizes of Solar PV panels available in India are from 5 W to 165W having 36 cells and output voltage of 12 volts. These panels can be configured in parallel and series to attain higher capacity. Due to its availability in lower unit sizes there is a flexibility in configuring bigger size.

Sizing Of Battery

The battery bank is sized to operate the loads during a sequence of below average insolation days, called the days of autonomy. In the design, days of autonomy is taken depending on the level of reliability required, which is normally two to three days. In battery sizing some other factors like maximum depth of discharge, temperature correction, rated battery capacity and battery life is considered. In this design depth of discharge is taken to be 65%. Temperature correction to account for decrease in battery efficiency at low temperature is taken 0.9. So the Required battery capacity in Ampere-hour (Ah) is given by expression 3 [12]

$$B_{rc} = \frac{E_{PV(Ah)} \times D_S}{(DOD)_{\max} \times \eta_T} \quad 3$$

where,

Ds – is battery autonomy or storage days;(DOD)*max* - maximum battery depth of discharge; η_T - temperature correction factor and B_{rc} - Required storage capacity

For one (1) kW solar PV panel and peak sun of 5.012 hrs the energy required to store per day is 0.601 kWh or 0.05 Ah/day for a 12 V battery assuming 85 % efficiency. So for days of autonomy to be two the size of 12 V battery required to be 1.42 Ah.

SIZING OF WIND TURBINE

Wind Turbine Average Power Output is the power produced at each wind speed multiplied by the fraction of the time that wind speed experienced.

Wind turbine relating power and wind speed is given by equation 4

$$P_w = \frac{1}{2} \times \eta \times C_p \times \rho \times A \times (v^3) \quad 4$$

As the wind potential in the study area is limited, therefore, the small capacity systems can be used to tap wind potential. In order to determine unit cost of the system a 3 meter long rotor diameter having efficiency is considered. At an average speed of 3 m/sec a 0 .5 kW wind turbine will yield 810 kWh/year assuming wind to be available 6 hours a day for 300 days in a year at load factor of 0.9..

The standard turbines available in India are of capacities 225 kW, 250 kW, 300 kW, 400 kW, 600 kW, 750 kW, 800 kW, 1000 kW and 1500 kW. In small capacities the turbines are designed as per site requirements..

4.5 COST OF ENERGY

It is essential to evaluate cost of energy of each of the energy conversion system to establish its viability. To evaluate project economically there are various techniques: like net present value method, internal rate of return method, return on investment, benefit cost ratio method and pay back period method. Out of these the Net present value methods are most commonly used. The Net Present Value Criterion (NPV) examines the cash flow of a project over a given period of time period and resolves them to one equivalent present date cash flow through the use of various economic factors. One mostly used such economic factor is capital recovery factor. The CRF resolves the cost of equipment in a series of annual cost taking into consideration the discount or interest rate and is given by expression 5 [13]

$$CRF = \frac{r(1+r)^n}{(1+r)^n - 1} \qquad 5$$

Where "*r*" is the discount rate and "*n*" is the period of evaluation in years.

The Capital cost, Annual maintenance cost, fuel cost and replacement cost are taken into account to determine the cost of energy. As the fuel component in case of IRES does not exist only the annual capital cost or amortization cost and maintenance cost is considered. The same can be represented in a modified version of economic method 6a and 6b[14]

$$C_{an} = \sum_i \left[\frac{r(1+r)^n \times C_i \times S_i}{((1+r)^n - 1)} + m \times AEG_i \right] \qquad 6a$$

$$COE = \frac{C_{an}}{AEG} \qquad 6b$$

C_{an} *,* Amortization Cost in Rs; C_i, Capital cost of components per unit capacity; *Si* is the capacity or size of the energy conversion system, *n*, Life of the component in year; *COE* Cost of energy; m_i is the maintenance cost per unit energy generation and Annual energy generation *(AEG)* is given by equation 7 and unit cost of generation by equation 8. 'k' is the load factor.

$$AEG = \sum_{i=1}^{n} \sum_{j=1}^{m} (k \times \eta_{ij} \times w_{ij}) \qquad 7$$

$$COE = CRF \times \frac{C_i \times S_i}{AEG_i} + m_i \qquad 8$$

For simplicity and to give a conservative estimate interest rates are quoted net of inflation at 7% (Discount rate 10% and General inflation 3%) [14] The life of Micro hydro unit, Biogas digester, Wind energy system and Solar PV is assumed to be 20 years. The capital recovery factor for all the components will therefore is as follows:

$$CRF = \frac{r(1+r)^n}{((1+r)^n - 1)} = 0.09439$$

The capital cost of Micro hydel, Producer gas (BES), Wind, Solar PV and D.G.Set units are taken Rs. 90/W, Rs 20/W Rs 125/W and Rs. 200/W , respectively. While the operating cost of Micro hydel, Producer gas (BES), Wind and Solar PV units are Rs.0.15/kWh, Rs.0.2/kWh Rs.0.1/kWh and Rs. 0.05/kWh, respectively[15]. The per cubic meter cost of biogas digester is Rs. 4500 [16] and the operation cost is assumed to be Rs. 0.15 /kWh. The costs of energy from various sources as calculated above have been presented on table 7.

Table 7: Cost of Energy from Various Sources

ITEM	Unit	Cost				
		HYDRO	BES	BGS	WIND	SPV
System rating	KW and *m^3	20	45	860	0.5	1
Ann. Energy generated,(AEG)	kWh/Year	149011	44423	347394	810	1352
Amortization period	Years	20	20	20	20	20
Capital Recovry Factor	CRF	0.09439	0.09439	0.09439	0.09439	0.09439
Cost per unit capacity	Rs/kW or *Rs/m^3	90000	20000	4500	125000	200000
Annual Maintenance Cost,($m_{i)}$	Rs/kWh	0.15	0.2	0.15	0.1	0.05
Cost of Energy (COE)	(Rs/kWh)	1.30	2.06	1.20	7.40	14

The unit cost of energy for MHP is 1.30 Rs/kWh, for Biomass energy system Rs.2.06 Rs./kWh, BGS is 1.20 Rs/kWh, Wind is 7.40 Rs./kWh and Solar PV is 14 Rs/kWh.

Conclusion

To study the use of Renewable energy resources for energy needs of rural area a remote village *Ramani* in *Chamoli* district of *Uttaranchal* has been selected village. The resources available locally and various energy requirements have been assessed. An attempt has been made to satisfy all the energy needs of the villagers from the available resources in most efficient and cost effective manner. A generalized optimization model for finding optimal combination of Integrated Renewable Energy System is developed to harness the renewable energy sources in remote area considering cost minimization and efficiency maximization. As a result of study following conclusions have emerged:

1 The hydro power potential in the village is estimated to be 149011 kWh/year. The village has cattle population for the biogas potential of 1350979 kWh/year. The Solar energy potential of 1503 kWh/year from a one kW solar panel is assessed.

2 The demand of energy for lighting is 124203 kWh/year, for cooking 227431 kWh/year and for grain grinding 9600 kWh/year.

3 The unit cost of energy for micro hydro (MHP) is 1.30 Rs./kWh; for Biomass conversion system (BES) is 2.00 Rs./kWh; for Biogas conversion system (BGS) 1.20 Rs./kWh; and for Solar PV 14 Rs./kWh.

4 In the concluding combination the ratings of various renewable energy systems is 20 kW for Micro Hydro Power, 870 m^3 for Biogas Digester, and 8 kW for SPV.

5 The model of efficient utilization of resources to meet energy needs yield optimal configuration of the system having cost of electricity Rs.2.64 per kWh and cost of energy for cooking 1.0 Rs/kWh and Cost of energy for rotating shaft Rs.1.30 per kWh.

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